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Hernández, Adriana Carolina Luna; Aldana, Nelson Leonardo Diaz; Graells, Moises; Guerrero, Josep M.; Quintero, Juan Carlos Vasquez

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Cooperative Management for a Cluster of Residential Prosumers

Adriana C. Luna*, Nelson L. Diaz*†, Moisès Graells‡, Josep M. Guerrero*, and Juan C. Vasquez*
*Dept. Energy Technology, Aalborg University, Aalborg, Denmark, http://www.microgrids.et.aau.dk/
acl@et.aau.dk, nda@et.aau.dk, joz@et.aau.dk, juq@et.aau.dk
†Faculty of Engineering, Universidad Distrital Francisco Jose de Caldas, Bogota, Colombia
‡Dept. Chemical Engineering, Universitat Politècnica de Catalunya (UPC), Barcelona, Spain

***Abstract*—This paper proposes an energy management system for coordinating distributed prosumers. The prosumers are residential microgrids which internally produce and consume energy for autonomous operation. However, better performance is achieved by cooperative operation with other prosumers neighbors. Experimental results validate the proposed strategy.**

I. Introduction

A microgrid is a coordinated aggregation of distributed generators, energy storage systems (ESSs) and loads which may operate in grid-connected or island-mode. Due to the coordinated operation, the microgrid can be seen as a single controllable entity which ensures local power balance and and reliable operation of the local power grid. In this sense, small-scale microgrids based on renewable energy sources (RESs) have been widely applied in order to reduce the dependence from the power grid, mainly in residential applications. Because of this, each small-scale residential microgrid can be considered as an energy 'prosumer' which consumes and produces energy based on local requirements and resources.

For an optimal operation of each prosumer, it is required an energy management system (EMS) which ensures the power balance of the local power system. To be more clear, the EMS schedules the operation of the distributed energy resources (DERs) by considering load requirements, while ensuring proper ESSs performance, and maximizing the use of renewable energy resources [1]. Particularly, microgrids based on RESs require ESSs in order to smooth the variations at the power generation and increase the local consumption rate of RESs generation [2]. At this sense, ESSs based on batteries continue being the most used in islanded microgrids, since they offer good commitment between price, availability and energy density [2], [3].

However, under islanded operation, prosumers based on RESs sometimes have to disconnect the load, or waste some available energy from the primary resource in order to avoid excessive discharge and overcharge of the ESSs. Nevertheless, a better performance can be achieved when an external power system supports the operation of the system. At this sense, a prosumer can cooperate with another neighbors in order to reach a better global performance and increase the reliability of the cooperative cluster of residential microgrids [4].

In this paper, a central EMS is proposed for ensuring an optimal operation of a cluster of islanded residential prosumers. The proposed strategy, considers cooperative operations between prosumers such as power sharing and storage energy balance. The performance of islanded prosumers is compared with cooperative performance. Experimental results are used in order to evaluate the proposed strategy.

II. Operation of Cluster of Prosumers

The increasing penetration of renewable generation is contributing to reduce the dependence of the power grid in in small-scale applications such as residential grids [2]. In particular, private owners want to ensure local power supply based on the installed DERs by maximizing the generation from RESs while ensuring safe operational conditions for the ESSs which ensure high lifespan on their installation. Indeed, the state of charge (SoC) of a battery should be limited within an safe rage (normally 50 to 90%) by regarding that the cycle life of batteries decreases with deep discharge, additionally overcharge may damage the batteries [2]. From the point of view of the residential owner, this is an important fact since the installation cost and replacement cost of batteries represents a big percentage of the total cost of the microgrid [5]. Because of that, the EMS should constrain the SoC of the batteries by shedding the load or curtailing the RESs generation during periods of low and high generation respectively.In other words, the main objective of the power scheduling performed by the EMS is to ensure a reliable supply of the load as long as safe SoC window is warranted.

Fig. 1 shows a neighborhood of (n) prosumers. In this case some of them use RESs based on photovoltaic (PV) generation while others use RESs based on wind turbine (WT) generation. Each prosumer is able to operate independently from their neighbors with its own local EMS. In order to simplify the analysis we will consider a neighborhood composed by $(n = 2)$ prosumers one with PV (prosumer 1) and the other with WT (prosumer 2) generation.

A. Islanded prosumers operation

Each prosumer uses a full-duplex communication channel for communication between the DERs and the EMS. The EMS defines the load connection and power references for the local RES unit based on an 24-h ahead optimal scheduling. Meanwhile, the ESS is responsible of keeping the balance between generation and consumption. Fig. 2 shows the scheduled load

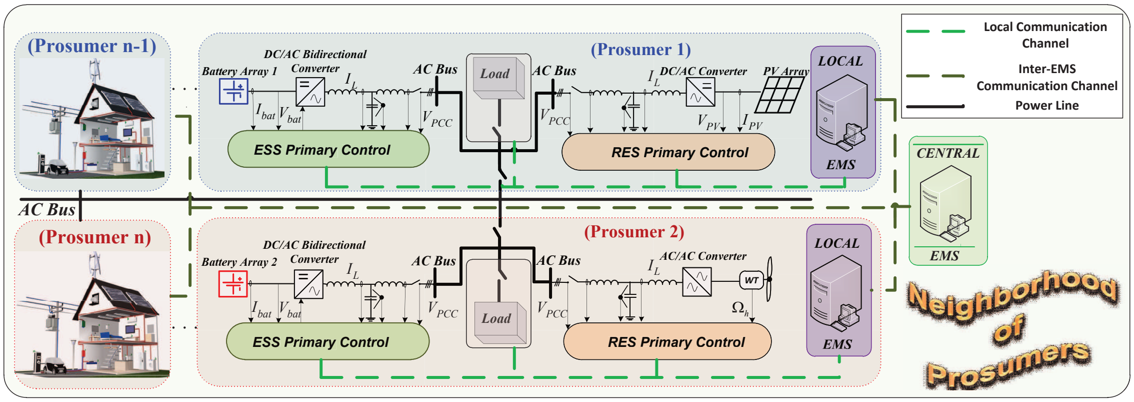

Fig. 1. Neighborhood of prosumers.

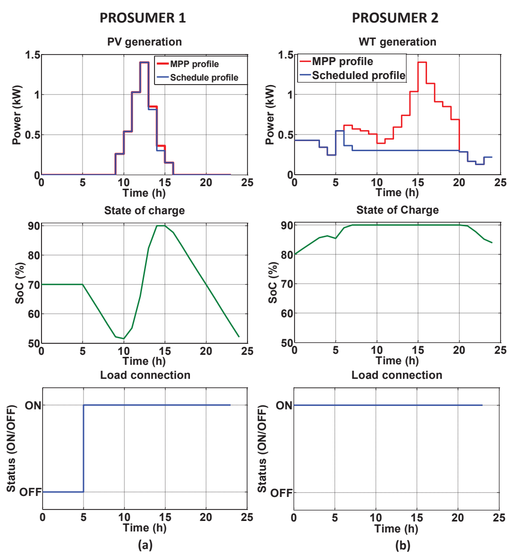

Fig. 2. Scheduled operation of islanded prosumers

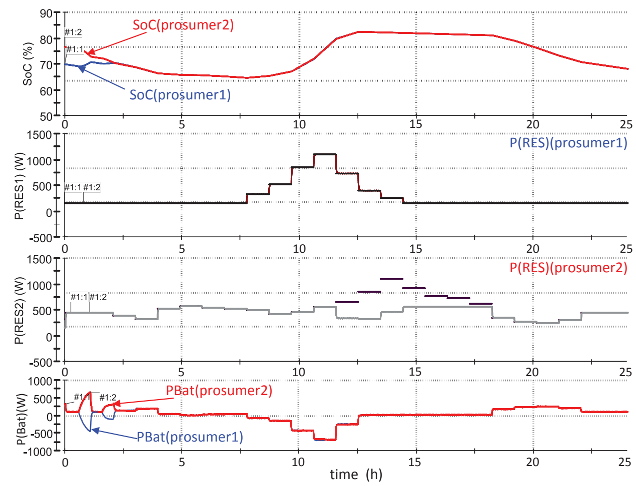

Fig. 3. Experimental result with central scheduling

connection and power generation for prosumer 1 (Fig. 2a) and prosumer 2 (Fig. 2b) respectively. Additionally, in Fig. 2 it is possible to see the expected behavior of the ESSs by considering a fixed load. In this figure we can see that while for the prosumer 1 the load has to bee shedding for five hours, in the case of the prosumer 2 the power generation at the WT is curtailed for more than 14 hours.

B. Cooperative prosumers operation

On top of that, a central EMS can coordinate the operation of the distributed prosumers in order to improve the performance of neighborhood. This improvement can be reflected in better loads profile connections and mayor usage of the renewable resources. On top of that, collaborative behaviors such a power sharing and stored energy balance between distributed ESSs can be easily addressed by the central EMS. In this case a dedicated duplex communication channel is considered between local and central EMS as can be seen in Fig. 1. Fig. 3 shows the experimental results obtained in the Microgrid Research Laboratory of Aalborg University [6]. Fig. 3 shows the SoC profile, PV and WT generation profiles and the power shared by distributes ESSs. In this case, the SoC is equalized between distributed ESSs. In addition, it is possible to see that PV generation is not curtailed and WT generation is only curtailed for 7 hours. Also, it is possible to see how the power is equally shared between distributed ESS. What is more, in this case the loads are not disconnected in order to keep the SoC in proper levels.

III. Conclusion

The proposed central EMS achieves better performance of the cluster of residential microgrids, considering RESs generation, due to the cooperation between prosumers. This strategy ensures the global balance of the system, while maximizing the use of distributed generators.

References

[1] M. Elsied, A. Oukaour, H. Gualous, and R. Hassan, “Energy management and optimization in microgrid system based on green energy,” *Energy*, vol. 84, pp. 139 – 151, 2015.

[2] P. Du and N. Lu, eds., *Energy Storage for Smart Grids*. Academic Press, first edition ed., 2015.

[3] I. S. C. C. 21, “Guide for optimizing the performance and life of lead-acid batteries in remote hybrid power systems,” *IEEE Std 1561-2007*, pp. C1–25, 2008.

[4] Q. Shafiee, T. Dragicevic, J. Vasquez, and J. Guerrero, “Hierarchical control for multiple dc-microgrids clusters,” *Energy Conversion, IEEE Transactions on*, vol. 29, pp. 922–933, Dec 2014.

[5] B. Mozafari and S. Mohammadi, “Optimal sizing of energy storage system for microgrids,” *Sadhana*, vol. 39, no. 4, pp. 819–841, 2014.

[6] A. University, “Research programme in microgrids, www.microgrids.et.aau.dk.,” August 2014.